# PureCycle® Product Development and Applications Update

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When field trials were first conducted in 2006 the PureCycle® product introduced a new concept in modular, packaged, quick to market organic rankine cycle power generation systems. Over 2008 and 2009 the PureCycle® system was deployed in number of applications including waste heat capture, both small scale (500kW) and large scale (10MW) geothermal power plants. The systems have performed exceptionally well with over 98% availability and exceeded expectations. Nevertheless, system improvements continue to be made.

This paper summarises the overall performance of the systems currently in operation, product features and their performance in the field, and new technical innovations that are being offered and considered by Pratt & Whitney Power Systems.

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## PureCycle® applications to date

The first field trial for PureCycle® was conducted in 2006 in Chena Springs, Alaska. Since that time standard water-cooled systems using the non-flammable working fluid R245fa have been deployed in numerous applications:

- 10MW at Raser Technologies' Utah plant, USA operating on geothermal brine (Fluid - geothermal brine from a hot sedimentary aquifer; Temperature – 121°C; Flow Rate: approx 19 l/s per unit). The system is water cooled using a common cooling tower.
- 2 units on a greenhouse operation in the USA operating on geothermal brine (Fluid - geothermal brine from a hot sedimentary aquifer; Temperature – 108°C; Flow Rate: approx 29 l/s per unit). The system is water-cooled using a common cooling tower.
- 1 unit on waste heat from diesel jacket water in Guatemala (Fluid – ethylene glycol; Temperature – 99°C; Flow Rate: approx 60 l/s per unit). The system is water cooled using a cooling tower.
- 1 unit at the Oregon Institute of technology for the first geothermal plant in Oregon (Fluid - geothermal brine from a hot sedimentary aquifer; Temperature – 88°C; Flow Rate: 21.5 l/s). The unit is water cooled using a cooling tower.
- 2 units on a waste to energy plant in Massachusetts (Fluid – one on low pressure steam and one on ethylene glycol; Temperature – 105C; Flow Rate: 4500 kg/hr (steam) & 65 kg/s)
- 1 unit using the thermal energy from an oil and gas well and operating on R134a (Fluid – co-produced fluids from an oil and gas well; Temperature – 85°C; Flow Rate: 54 l/s)
- The rate of enquiries and equipment orders is increasing. Based on the existing pipeline of opportunities we would expect this number to substantially increase with the continued strengthening of geothermal markets, and increasing focus on waste heat recovery and energy efficiency in industrial and oil and gas markets.

## Performance summary

To date the equipment across all applications is operating at > 98% availability. Power output has been consistent with the theoretical models developed in the UTC Research Centre in East Hartford, Connecticut.

## Technical innovations on the Model 280

The product development team continue to make system improvements that increase efficiency, broaden the variety of suitable applications, and provide the ability to operate in with zero water for cooling. Key additions to the product include:

- Air condenser for use in areas with limited access to water. The refrigerant is condensed directly in the air-condenser to maximise heat transfer.
- Recuperator that improves the cycle efficiency on the air and water cooled systems. This works by capturing the waste heat from the turbine exhaust and pre-heating the incoming hot liquid prior to the evaporator.
- Coatings and equipment modifications such as those necessary for a high H2S environment in some international geothermal fields.
- High pressure evaporators may also be selected on a case by case basis for some applications.

## Australian and New Zealand applications

Based on the previous 12-18 months of discussions with potential customers, the key applications for utilising low grade heat in Australia and New Zealand are:

- Waste heat from reciprocating engines operating on a variety of fuels (diesel, natural gas, landfill gas, sewage digester gas)
- Waste heat from biomass plants (sawmill waste and other mixed wastes)
- Waste heat from industrial processes and fossil fuel power generation (steel, aluminium, foundries, gas turbines)
- Low temperature geothermal applications

Analysis of the opportunities suggests that the following principles apply:

- Prices for the major generating plant in Australia are often more attractive than in New Zealand due to the relative strength of the AUD against the USD and Euro, making any internationally sourced equipment cheaper in Australia.
- High-priced diesel generation is attractive due to the high cost of fuel and low resource risk (the amount and flow of heat is easily quantified)
- The effective revenue gained from generating power on-site is higher than selling to the wholesale market
- Renewable energy certificates (RECs) improve the financial performance of projects developed in Australia where the waste heat is derived from renewable fuels.
- Waste heat is easier to quantify and more certain than geothermal resources, but less plentiful. There is some resource uncertainty as the waste heat is only available as long as the host industry continues to operate.

Figure 1 outlines a summary of where PureCycle® is likely to be most cost effective.

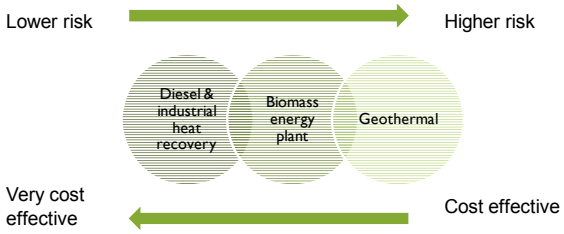


Figure 1: Cost effective PureCycle® applications

Nevertheless, the future looks bright for Australian and New Zealand geothermal, as well as waste heat applications.

## The future and corporate update

PWPS has embraced and enhanced the PureCycle® model 280 since taking over the product from its sister company – UTC Power in early 2009. The PureCycle® sits alongside gas turbines in its industrial power division.

For geothermal applications, generation of power from the Next Generation PureCycle® using resource temperatures at top of hole of up to 175°C should be achievable. Target pricing is confidential, but has been set at a point to ensure competitiveness in generating primary utility-grade power from geothermal power plants. A firm release date has not yet been set.

## Conclusion

There is a wide variety of economic applications available that suit the current PureCycle® Model 280, which continues to prove its reliability in the field, including waste heat from engines, geothermal, and industrial waste heat. Australia is generally a more attractive market than New Zealand due to the lower geothermal temperatures, better exchange rate, and supportive policy environment. The range of suitable applications is widening as the team at PWPS broaden the product offering and capability of the unit with technical innovations.